SLANT ENTRY WELL SYSTEM AND METHOD

TECHNICAL FIELD OF THE INVENTION

The present invention relates generally to systems and methods for the recovery of subterranean resources and, more particularly, to a slant entry well system and method.

BACKGROUND OF THE INVENTION

Subterranean deposits of coal contain substantial quantities of entrained methane gas. Limited production and use of methane gas from coal deposits has occurred for many years. Substantial obstacles, however, have frustrated more extensive development and use of methane gas deposits in coal seams. The foremost problem in producing methane gas from coal seams is that while coal seams may extend over large areas of up to several thousand acres, the coal seams are fairly shallow in depth, varying from a few inches to several meters. Thus, while the coal seams are often relatively near the surface, vertical wells drilled into the coal deposits for obtaining methane gas can only drain a fairly small radius around the coal deposits. Further, coal deposits are not amenable to pressure fracturing and other methods often used for increasing methane gas production from rock formations. As a result, once the gas easily drained from a vertical well bore in a coal seam is produced, further production is limited in volume. Additionally, coal seams are often associated with subterranean water, which must be drained from the coal seam in order to produce the methane.

Horizontal drilling patterns have been tried in order to extend the amount of coal seams exposed to a drill bore for gas extraction. Such horizontal drilling techniques, however, require the use of a radiused well bore which presents difficulties in removing the entrained water from the coal seam. The most efficient method for pumping water from a subterranean well, a sucker rod pump, does not work well in horizontal or radiused bores.

As a result of these difficulties in surface production of methane gas from coal deposits, which must be removed from a coal seam prior to mining, subterranean methods have been employed. While the use of subterranean methods allows water to be easily removed from a coal seam and eliminates under-balanced drilling conditions, they can only access a limited amount of the coal seams exposed by current mining operations. Where longwall mining is practiced, for example, underground drilling rigs are used to drill horizontal holes from a panel currently being mined into an adjacent panel that will later be mined. The limitations of underground rigs limits the reach of such horizontal holes and thus the area that can be effectively drained. In addition, the degasification of a next panel during mining of a current panel limits the time for degasification. As a result, many horizontal bores must be drilled to remove the gas in a limited period of time. Furthermore, in conditions of high gas content or migration of gas through a coal seam, mining may need to be halted or delayed until a next panel can be adequately degasified. These production delays add to the expense associated with degasifying a coal seam.

SUMMARY OF THE INVENTION

The present invention provides a slant entry well system and method for accessing a subterranean zone from the surface that substantially eliminates or reduces the disadvantages and problems associated with previous systems and methods. In particular, certain embodiments of the present invention provide a slant entry well system and method for efficiently producing and removing entrained methane gas and water from a coal seam without requiring excessive use of radiused or articulated well bores or large surface area in which to conduct drilling operations.

In accordance with one embodiment of the present invention, a system for accessing a subterranean zone from the surface includes an entry well bore extending down from the surface. A plurality of slanted well bores extend from the entry well bore to the subterranean zone. Drainage patterns extend from the slanted well bores into the subterranean zone.

According to another embodiment of the present invention, a method for accessing a subterranean zone from the surface includes forming an entry well bore and forming a plurality of slanted well bores from the entry well bore to the subterranean zone. The method also includes forming drainage patterns from the slanted well bores into the subterranean zone.

In accordance with still another embodiment of the present invention, a method for orienting well bores includes forming an entry well bore from the surface and inserting a guide tube bundle into the entry well bore. The guide tube bundle includes a plurality of guide tubes. The guide tubes are configured longitudinally

adjacent to one another and include a first aperture at a first end and a second aperture at a second end. The guide tubes may also be twisted around one another. A method also includes forming a plurality of slanted well bores from the entry well bore through the guide tube bundle to a subterranean zone.

Embodiments of the present invention may provide one or more technical advantages. These technical advantages may include the formation of an entry well bore, a plurality of slanted well bores, and drainage patterns to optimize the area of a subsurface formation which may be drained of gas and liquid resources. This allows for more efficient drilling and production and greatly reduces costs and problems associated with other systems and methods. Another technical advantage includes providing a method for orienting well bores using a guide tube bundle inserted into an entry well bore. The guide tube bundle allows for the simple orientation of the slant well bores in relation to one another and optimizes the production of resources from subterranean zones by optimizing the spacing between the slanted well bores.

Other technical advantages of the present invention will be readily apparent to one skilled in the art from the following figures, descriptions, and claims.

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BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and its advantages, reference is now made to the following description taken in conjunction with the accompanying drawings, wherein like numerals represent like parts, in which:

FIGURE 1 illustrates an example slant well system for production of resources from a subterranean zone;

FIGURE 2A illustrates a vertical well system for production of resources from a subterranean zone;

FIGURE 2B illustrates a portion of An example slant entry well system in further detail;

FIGURE 3 illustrates an example method for producing water and gas from a subsurface formation;

FIGURES 4A-4C illustrate construction of an example guide tube bundle;

FIGURE 5 illustrates an example entry well bore with an installed guide tube bundle;

FIGURE 6 illustrates the use of an example guide tube bundle in an entry well bore;

FIGURE 7 illustrates an example system of slanted well bores;

FIGURE 8 illustrates an example system of an entry well bore and a slanted well bore;

FIGURE 9 illustrates an example system of a slanted well bore and an articulated well bore;

FIGURE 10 illustrates production of water and gas in an example slant well system;

FIGURE 11 illustrates an example drainage pattern for use with a slant well system; and

FIGURE 12 illustrates an example alignment of drainage patterns for use with a slant well system.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1 illustrates an example slant well system for accessing a subterranean zone from the surface. In the embodiment described below, the subterranean zone is a coal seam. It will be understood that other subterranean formations and/or low pressure, ultra-low pressure, and low porosity subterranean zones can be similarly accessed using the slant well system of the present invention to remove and/or produce water, hydrocarbons and other fluids in the zone, to treat minerals in the zone prior to mining operations, or to inject or introduce fluids, gases, or other substances into the zone.

Referring to FIGURE 1, a slant well system 10 includes an entry well bore 15, slant wells 20, articulated well bores 24, cavities 26, and rat holes 27. Entry well bore 15 extends from the surface 11 towards the subterranean zone 22. Slant wells 20 extend from the terminus of entry well bore 15 to the subterranean zone 22, although slant wells 20 may alternatively extend from any other suitable portion of entry well bore 15. Where there are multiple subterranean zones 22 at varying depths, as in the illustrated example, slant wells 20 extend through the subterranean zones 22 closest to the surface into and through the deepest subterranean zone 22. Articulated well bores 24 may extend from each slant well 20 into each subterranean zone 22. Cavity 26 and rat hole 27 are located at the terminus of each slant well 20.

In FIGURES 1, and, 5-8, entry well bore 15 is illustrated as being substantially vertical; however, it should be understood that entry well bore 15 may be

formed at any suitable angle relative to the surface 11 to accommodate, for example, surface 11 geometries and attitudes and/or the geometric configuration or attitude of a subterranean resource. In the illustrated embodiment, slant well 20 is formed to angle away from entry well bore 15 at an angle designated alpha, which in the illustrated embodiment is approximately 20 degrees. It will be understood that slant well 20 may be formed at other angles to accommodate surface topologies and other factors similar to those affecting entry well bore 15. Slant wells 20 are formed in relation to each other at an angular separation of beta degrees, which in the illustrated embodiment is approximately sixty degrees. It will be understood that slant wells 20 may be separated by other angles depending likewise on the topology and geography of the area and location of the target coal seam 22.

Slant well 20 may also include a cavity 26 and/or a rat hole 27 located at the terminus of each slant well 20. Slant wells 20 may include one, both, or neither of cavity 26 and rat hole 27.

FIGURES 2A and 2B illustrate by comparison the advantage of forming slant wells 20 at an angle. Referring to FIGURE 2A, a vertical well bore 30 is shown with an articulated well bore 32 extending into a coal seam 22. As shown by the illustration, fluids drained from coal seam 22 into articulated well bore 32 must travel along articulated well bore 32 upwards towards vertical well bore 30, a distance of approximately *W* feet before they may be collected in vertical well bore 30. This distance of *W* feet is known as the hydrostatic head and must be overcome before the fluids may be collected

from vertical well bore 30. Referring now to FIGURE 2B, a slant entry well 34 is shown with an articulated well bore 36 extending into coal seam 22. Slant entry well 34 is shown at an angle alpha away from the vertical. As illustrated, fluids collected from coal seam 22 must travel along articulated well bore 36 up to slant entry well 34, a distance of *W'* feet. Thus, the hydrostatic head of a slant entry well system is reduced as compared to a substantially vertical system. Furthermore, by forming slant entry well 34 at angle alpha, the articulated well bore 36 drilled from tangent or kick off point 38 has a greater radius of curvature than articulated well bore 32 associated with vertical well bore 30. This allows for articulated well bore 36 to be longer than articulated well bore 32 (since the friction of a drill string against the radius portion is reduced), thereby penetrating further into coal seam 22 and draining more of the subterranean zone.

FIGURE 3 illustrates an example method of forming a slant entry well. The steps of FIGURE 3 will be further illustrated in subsequent FIGURES 4-11. The method begins at step 100 where the entry well bore is formed. At step 105, a fresh water casing or other suitable casing with an attached guide tube bundle is installed into the entry well bore formed at step 100. At step 110, the fresh water casing is cemented in place inside the entry well bore of step 100.

At step 115, a drill string is inserted through the entry well bore and one of the guide tubes in the guide tube bundle. At step 120, the drill string is used to drill approximately fifty feet past the casing. At step 125, the drill is oriented to the desired angle of the

slant well and, at step 130, a slant well bore is drilled down into and through the target subterranean zone.

At decisional step 135, a determination is made whether additional slant wells are required. If additional slant wells are required, the process returns to step 115 and repeats through step 135. Various means may be employed to guide the drill string into a different guide tube on subsequent runs through steps 115-135, which should be apparent to those skilled in the art.

If no additional slant wells are required, the process continues to step 140. At step 140 the slant well casing is installed. Next, at step 145, a short radius curve is drilled into the target coal seam. Next, at step 150, a substantially horizontal well bore is drilled into and along the coal seam. It will be understood that the substantially horizontal well bore may depart from a horizontal orientation to account for changes in the orientation of the coal seam. Next, at step 155, a drainage pattern is drilled into the coal seam through the substantially horizontal well. At decisional step 157, a determination is made whether additional subterranean zones are to be drained as, for example, when multiple subterranean zones are present at varying depths below the surface. If additional subterranean zones are to be drained, the process repeats steps 145 through 155 for each additional subterranean zone. If no further subterranean zones are to be drained, the process continues to step 160.

At step 160, production equipment is installed into the slant well and at step 165 the process ends with the production of water and gas from the subterranean zone.

Although the steps have been described in a certain order, it will be understood that they may be performed in any other appropriate order. Furthermore, one or more steps may be omitted, or additional steps performed, as appropriate.

FIGURES 4A, 4B, and 4C illustrate formation of a casing with associated guide tube bundle as described in step 105 of FIGURE 3. Referring to FIGURE 4A, three guide tubes 40 are shown in side view and end view. The guide tubes 40 are arranged so that they are parallel to one another. In the illustrated embodiment, guide tubes 40 are 9 5/8" joint casings. It will be understood that other suitable materials may be employed.

FIGURE 4B illustrates a twist incorporated into guide tubes 40. The guide tubes 40 are twisted gamma degrees in relation to one another while maintaining the lateral arrangement to gamma degrees. Guide tubes 40 are then welded or otherwise stabilized in place. In an example embodiment, gamma is equal to 10 degrees.

FIGURE 4C illustrates guide tubes 40, incorporating the twist, in communication and attached to a casing collar 42. The guide tubes 40 and casing collar 42 together make up the guide tube bundle 43, which may be attached to a fresh water or other casing sized to fit the length of entry well bore 15 of FIGURE 1 or otherwise suitably configured.

FIGURE 5 illustrates entry well bore 15 with guide tube bundle 43 and casing 44 installed in entry well bore 15. Entry well bore 15 is formed from the surface 11 to a target depth of approximately three hundred and ninety feet. Entry well bore 15, as illustrated, has a diameter of approximately twenty-four inches. Forming entry well

bore 15 corresponds with step 100 of FIGURE 3. Guide tube bundle 43 (consisting of joint casings 40 and casing collar 42) is shown attached to a casing 44. Casing 44 may be any fresh water casing or other casing suitable for use in down-hole operations. Inserting casing 44 and guide tube bundle 43 into entry well bore 15 corresponds with step 105 of FIGURE 3.

Corresponding with step 110 of FIGURE 3, a cement retainer 46 is poured or otherwise installed around the casing inside entry well bore 15. The cement casing may be any mixture or substance otherwise suitable to maintain casing 44 in the desired position with respect to entry well bore 15.

FIGURE 6 illustrates entry well bore 15 and casing 44 with guide tube 43 in its operative mode as slant wells 20 are about to be drilled. A drill string 50 is positioned to enter one of the guide tubes 40 of guide tube bundle 43. In order to keep drill string 50 relatively centered in casing 44, a stabilizer 52 may be employed. Stabilizer 52 may be a ring and fin type stabilizer or any other stabilizer suitable to keep drill string 50 relatively centered. To keep stabilizer 52 at a desired depth in well bore 15, stop ring 53 may be employed. Stop ring 53 may be constructed of rubber or metal or any other foreign down-hole environment material suitable. Drill string 50 may be inserted randomly into any of a plurality of guide tubes 40 of guide tube bundle 43, or drill string 50 may be directed into a selected joint casing 40. This corresponds to step 115 of FIGURE 3.

FIGURE 7 illustrates an example system of slant wells 20. Corresponding with step 120 of FIGURE 3,

tangent well bore 60 is drilled approximately fifty feet past the end of entry well bore 15 (although any other appropriate distance may be drilled). Tangent well bore 60 is drilled away from casing 44 in order to minimize magnetic interference and improve the ability of the drilling crew to guide the drill bit in the desired direction. Corresponding with step 125 of FIGURE 3, a radiused well bore 62 is drilled to orient the drill bit in preparation for drilling the slant entry well bore 64. In a particular embodiment, radiused well bore 62 is curved approximately twelve degrees per one hundred feet (although any other appropriate curvature may be employed).

Corresponding with step 130 of FIGURE 3, a slant entry well bore 64 is drilled from the end of the radius well bore 62 into and through the subterranean zone 22. Alternatively, slant well 20 may be drilled directly from guide tube 40, without including tangent well bore 60 or radiused well bore 62. An articulated well bore 65 is shown in its prospective position but is drilled later in time than rat hole 66, which is an extension of slant well 64. Rat hole 66 may also be an enlarged diameter cavity or other suitable structure. After slant entry well bore 64 and rat hole 66 are drilled, any additional desired slant wells are then drilled before proceeding to installing casing in the slant well.

FIGURE 8 is an illustration of the casing of a slant well 64. For ease of illustration, only one slant well 64 is shown. Corresponding with step 140 of FIGURE 3, a whip stock casing 70 is installed into the slant entry well bore 64. In the illustrated embodiment, whip stock casing 70 includes a whip stock 72 which is used to

mechanically direct a drill string into a desired orientation. It will be understood that other suitable casings may be employed and the use of a whip stock 72 is not necessary when other suitable methods of orienting a drill bit through slant well 64 into the subterranean zone 22 are used.

Casing 70 is inserted into the entry well bore 15 through guide tube bundle 43 and into slant entry well bore 64. Whip stock casing 70 is oriented such that whip stock 72 is positioned so that a subsequent drill bit is aligned to drill into the subterranean zone 22 at the desired depth.

FIGURE 9 illustrates whip stock casing 70 and slant entry well bore 64. As discussed in conjunction with FIGURE 8, whip stock casing 70 is positioned within slant entry well bore 64 such that a drill string 50 will be oriented to pass through slant entry well bore 64 at a desired tangent or kick off point 38. This corresponds with step 145 of FIGURE 3. Drill string 50 is used to drill through slant entry well bore 64 at tangent or kick off point 38 to form articulated well bore 36. In a particular embodiment, articulated well bore 36 has a radius of approximately seventy-one feet and a curvature of approximately eighty degrees per one hundred feet. In the same embodiment, slant entry well 64 is angled away from the vertical at approximately ten degrees. In this embodiment, the hydrostatic head generated in conjunction with production is roughly thirty feet. However, it should be understood that any other appropriate radius, curvature, and slant angle may be used.

FIGURE 10 illustrates a slant entry well 64 and articulated well bore 36 after drill string 50 has been

used to form articulated well bore 36. In a particular embodiment, a horizontal well and drainage pattern may then be formed in subterranean zone 22, as represented by step 150 and step 155 of FIGURE 3.

Referring to FIGURE 10, whip stock casing 70 is set on the bottom of rat hole 66 to prepare for production of oil and gas. A sealer ring 74 may be used around the whip stock casing 70 to prevent gas produced from articulated well bore 36 from escaping outside whip stock casing 70. Gas ports 76 allow escaping gas to enter into and up through whip stock casing 70 for collection at the surface.

A pump string 78 and submersible pump 80 is used to remove water and other liquids that are collected from the subterranean zone through articulated well bore 36. As shown in FIGURE 10, the liquids, under the power of gravity and the pressure in subterranean zone 22, pass through articulated well bore 36 and down slant entry well bore 64 into rat hole 66. From there the liquids travel into the opening in the whip stock 72 of whip stock casing 70 where they come in contact with the installed pump string 78 and submersible pump 80. Submersible pump 80 may be a variety of submersible pumps suitable for use in a down-hole environment to remove liquids and pump them to the surface through pump string 78. Installation of pump string 78 and submersible pump 80 corresponds with step 160 of FIGURE 3. Production of liquid and gas corresponds with step 165 of FIGURE 3.

FIGURE 11 illustrates an example drainage pattern 90 that may be drilled from articulated well bores 36. At the center of drainage pattern 90 is entry well bore 15. Connecting to entry well bore 15 are slant wells 20. At

the terminus of slant well 20, as described above, are substantially horizontal well bores 92 roughly forming a "crow's foot" pattern off of each of the slant wells 20. As used throughout this application, "each" means all of a particular subset. In a particular embodiment, the horizontal reach of each substantially horizontal well bore 92 is approximately fifteen hundred feet. Additionally, the lateral spacing between the parallel substantially horizontal well bores 92 is approximately eight hundred feet. In this particular embodiment, a drainage area of approximately two hundred and ninety acres would result. In an alternative embodiment where the horizontal reach of the substantially horizontal well bore 92 is approximately two thousand four hundred and forty feet, the drainage area would expand to approximately six hundred and forty acres. However, any other suitable configurations may be used. Furthermore, any other suitable drainage patterns may be used.

FIGURE 13 illustrates a plurality of drainage patterns 90 in relationship to one another to maximize the drainage area of a subsurface formation covered by the drainage patterns 90. Each drainage pattern 90 forms a roughly hexagonal drainage pattern. Accordingly, drainage patterns 90 may be aligned, as illustrated, so that the drainage patterns 90 form a roughly honeycomb-type alignment.

Although the present invention has been described with several embodiments, various changes and modifications may be suggested to one skilled in the art. It is intended that the present invention encompass such changes and modifications as fall within the scope of the appended claims.